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Climate change driven treeline shifts in Northern Russia are fostered by an improving nutrient availability

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Treelines are distinct vegetation boundaries from tundra to forests. They have shifted upward during the last decades in various mountain regions around the globe, which has mainly been attributed to climate warming. In our study, we examined the influence of nutrient availability on treeline shifts. We hypothesized that a more favorable microclimate in the forest as compared to tundra enhances nutrient mineralization which in turn fosters the forest expansion. In remote areas of the Ural and Khibiny mountains of Northern Russia, we have sampled plants and soils along six elevational transects reaching from the tundra to subalpine forests, representing treeline shifts in a space for time approach. We have analyzed contents of the two major nutrients, nitrogen (N) and phosphorus (P) in various soil pools and plant tissues.
Our results show that total N and P pools in the soil do not change significantly along the elevational transects. In contrast, mineral N and available P (PBray and resin-extractable P) increase significantly from the tundra to the subalpine or subarctic forest. At the tundra, available P accounts for 0.5% of total P and increases to up to 3% in the mature forest. This indicates that net nutrient mineralization increased with forest expansion. In agreement, foliar N and P contents of trees were also greater in the forest than at the treeline and in the tundra. Moreover, increasing δ15N value towards the forest also signify an improving N nutritional status. The increase in foliage nutrients occurred despite a five-fold increase in biomass productivity, indicating that the positive effect of the forest on nutrient mobilization was greater than an increased binding of nutrients in tree biomass. We relate the improved nutrient availability towards the forest to a more favorable microclimate especially during winter, where soil temperature were more than 5°C warmer in the forest than in the tundra due to a thicker insulating snow cover. In addition, tree roots and associated mycorrhizal communities may have a greater capability in mobilizing nutrients than tundra plants. Our results suggest that nutrient-poor conditions in cool tundra soils may hamper treeline advances and they show that there is a positive feedback between forest establishment in tundra and nutrient availability in a warming climate.